Bean diseases and their control

Agriculture Canada

Publication 1758/E

Canada

Agriculture Canada Publication 1758/E
available from
Communications Branch, Agriculture Canada
Ottawa K1A 0C7

Cat. No. A53-1758/1984E ISBN: 0-662-12933-4
Printed 1984 Reprinted 1989 3M-7:89

Également disponible en français sous le titre
Maladies des haricots et moyens de lutte.

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Recommendations for pesticide use in this publication are intended as guidelines only. Any application of a pesticide must be in accordance with directions printed on the product label of that pesticide as prescribed under the *Pest Control Products Act*. ALWAYS READ THE LABEL. A registered pesticide should also be recommended by provincial authorities. Because recommendations for use may vary from province to province, your provincial agricultural representative should be consulted for specific advice.

Bean diseases and their control

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Introduction

This publication covers navy (or white or pea), colored, kidney, snap, and garden beans, which all belong to one species, *Phaseolus vulgaris*. The first three are generally cropped as dry beans and the last two as green beans.

In Canada, dry beans are grown chiefly in the southern regions of Ontario and to a lesser extent in Quebec. Yearly production of dry beans in Ontario and Quebec is approximately 100 000 t, with a total value of about $65 million. Canada is a major exporter of dry beans, second only to the United States.

Green beans are grown in home gardens across the southern part of Canada. Commercial processing operations are found in southern Ontario and British Columbia, mainly for fresh market, canning, and freezing. Green bean consumption in Canada totals about 46 000 t per year, or about 2 kg per person. Most green beans are imported from the United States, and therefore an increase in Canadian production is needed.

One of the many factors that affect the production of beans is disease. There are over 50 diseases known to affect beans, of which 15–20 are commonly found in Canada; only about 10 are of practical economical importance. This publication is intended to serve as a guide for disease control and to help the Canadian grower and extension officer to recognize bean diseases.

A registered pesticide should also be recommended by provincial authorities. Because recommendations may vary from province to province, consult your provincial agricultural representative for specific advice.

Causes of disease

Many groups of organisms can cause plant disease, and nonpathogenic factors can cause disorders. Organisms include fungi, bacteria, viruses, mycoplasmas, and nematodes. Nonpathogenic factors include nutritional deficiencies, toxicity disorders, and injuries.

Fungi

Fungi are plants whose cells have a true nucleus and do not contain chlorophyll. They live on dead organic matter or on other living plants, or both, and vary greatly in size and shape. Mushrooms and puffballs, which grow on lawns, wood, and trees, are fruiting bodies of fungi. Rusts, smuts, and mildews that develop on living plants are also fruiting structures of fungi. Fungi cause many diseases in beans. Anthracnose, damping-off, gray mold, root rot, rust, and white

mold are fungal diseases that are commonly found in Canada and occasionally cause heavy yield losses.

Bacteria

Bacteria are single-celled microscopic organisms that do not have true nuclei. The slimy residue on rotten vegetables, such as soft rot of cabbage or onion, are bacterial masses. Bacteria enter plant tissues through natural openings or wounds. The infected tissues usually have a water-soaked appearance. Of the many bacterial diseases that affect beans, the most important are bacterial blights.

Mycoplasmas

Mycoplasmas do not have cell walls, thus resembling naked bacteria, and they multiply by fission and budding. They vary in size from somewhat smaller to somewhat bigger than bacteria. Mycoplasmas are transmitted from diseased plants to healthy ones by leafhoppers, and they multiply inside the leafhoppers. Diseased plants often become yellow, dwarfed, bushy, or leafy. The witches'-broom disease is caused by a mycoplasma.

Viruses

Viruses can be seen only through an electron microscope. Morphologically, they are of two forms, spherical (or polyhedral) and rod-shaped (or cylindrical).

Irrespective of morphology, they are biologically active and can replicate within a host cell. Some plant viruses can persist in dry plant tissue or seeds for long periods, whereas others cannot. Viruses can be transmitted by seeds, sap, cuttings, scions, insects, mites, and nematodes. The mode of transmission varies from virus to virus.

Virus diseases that are economically important in the bean-growing areas of Canada are bean common mosaic virus, bean yellow mosaic virus, and tobacco ringspot virus. There are other viruses that can infect beans but they are not of major importance.

Nematodes

Nematodes are colorless, threadlike animals about 0.4–3 mm long. They live in soil, feeding on other organisms and organic debris, or on living plant roots. Saprophytic nematodes are bigger and are often visible to the naked eye, and parasitic nematodes are usually microscopic. Some parasitic nematodes can injure plant roots, cause root knot disease, and transmit viral diseases.

Nutrient deficiencies

When normal growth requirements of plants are not met, signs of deficiency develop. Low-level deficiencies can remain undetected, simply resulting in poor growth and yield reduction. However, when deficiencies of soil nutrients, especially nitrogen, phosphorus, potassium, magnesium, manganese, calcium, and iron, reach critical thresholds, specific deficiency symptoms occur, such as

yellowing, vein chlorosis, veinclearing, mottling, puckering, and tip curl, for example. Such disorders can be remedied by applying needed nutrients. It must be noted that many deficiencies of microelements such as magnesium, manganese, calcium, and iron are imposed by undesirable soil pH that alters the ionic form of the nutrient and renders it unavailable to the plants. In such cases, soil pH should be adjusted by an appropriate soil amendment, such as lime or sulfur.

Toxicity disorders

Toxicities are induced by excessive amounts of materials. Fertilizers and herbicides applied in excess cause leaf burn and toxicity in plants. Herbicide residues of previous seasons may be toxic to subsequent crops. For example, atrazine applied to corn may leave enough residue to cause injury or death of beans. High concentrations of pollutants (ozone and sulfur dioxide) also cause toxicity disorders. In beans, bronzing is caused by ozone injury. Excessive salinity, alkalinity, and acidity are hazardous to plant growth.

Injuries

Beans are highly subject to injuries. The most common causes are frost, hail, sandblasting, sunscald, and lightning.

Prevention of disease

Disease control should start with disease prevention. Adequate preventive measures can keep disease losses at a minimum. In fact, correct farm management, cultural practices, and crop hygiene are often sufficient to alleviate many diseases without resorting to chemical sprays.

Farm management

Choosing a crop, selecting a cultivar, improving soil drainage, and monitoring soil pH are several management practices that affect plant diseases.

- *Crop selection.* Match the crop to the soil type to ensure good plant growth and decrease the incidence of disease.
- *Cultivar selection.* Use cultivars of high yield and satisfactory disease resistance (follow provincial recommendations or consult seed catalogs).
- *Soil drainage improvement.* Provide well-drained soil to increase root development and reduce the incidence and severity of damping-off and root rots.
- *Monitoring soil pH.* Maintain proper soil pH to help plant growth and development. A correct pH level also decreases the incidence of disease. For example, in acidic soil, beans tend to develop more root rot and produce fewer root nodules. In such cases, liming may help.

Cultural practices

Crop rotation, soil preparation, row spacing, seeding rate, and correct application of fertilizer are among the cultural practices important to disease management.

- *Crop rotation.* Rotate crops to reduce buildup of disease and insects as well as toxic substances in the soil. Crop rotation also ensures balanced utilization of soil nutrients.
- *Soil preparation.* Provide well-planned drainage to improve aeration and development of roots, thus reducing seed rot, damping-off, and root rots.
- *Row spacing and seeding rate.* Allow enough space between rows; narrow rows and dense seeding reduce aeration and provide a humid canopy that encourages the introduction and spread of diseases. This is especially true for white mold.
- *Application of fertilizer.* Do not overfertilize. Although an adequate amount of fertilizer increases yield, an excessive amount is a waste of money and often renders plants more susceptible to disease. Excessive amounts of nitrogen, especially, have been shown to promote disease.

Crop hygiene

The use of disease-free seed and seed treatment are of primary importance in crop hygiene. Weed control, insect control, and debris handling are also significant in disease management.

- *Disease-free seeds.* Use certified seeds whenever possible. Many disease organisms are carried in or on the seed. Bean diseases such as common mosaic, anthracnose, and bacterial blight are seed borne. Certified seeds have been inspected to ensure that they are free of seed-borne diseases.
- *Seed treatment.* Treat all seeds with an approved fungicide, regardless of whether or not the seed appears to be free of seed-borne diseases. The fungicide formula varies with the purpose.
- *Weed control.* Keep weeds well under control. They can greatly reduce bean yields, and many perennial species harbor viruses. Weed canopies impede aeration of the crop and can lead to severe outbreaks of leaf and pod diseases that flourish in a humid atmosphere.
- *Insect control.* Control insects before they become a problem. Many insects feed on plants. They not only damage the plant but may also spread disease. Many virus diseases are spread by insects such as aphids, leafhoppers, thrips, and beetles.
- *Handling of debris.* Plow down healthy plant debris to hasten decomposition. Diseased debris should be either burned or plowed into the soil, depending on the nature of the pathogen. For example, the bean anthracnose fungus survives easily into the next season in dry debris; thus debris in piles increases the chance of fungal survival.

Fungal diseases

There are over 40 fungal diseases that can affect bean plants. Only those that are important in Canada are discussed and only those of major importance are discussed in detail.

Bean anthracnose

Bean anthracnose, caused by the fungus *Colletotrichum lindemuthianum*, is almost worldwide in distribution. Anthracnose affects yield, seed quality, and marketability of beans. It is more prevalent in the temperate zones than in the tropics. There are at least six major races of the fungus (alpha, beta, gamma, delta, lambda, and kappa), which are characterized by the cultivars they attack. Before 1976, only three races (alpha, beta, and gamma) were known to exist in North America. Cultivars of beans had been bred for resistance to one or more of the three races. Consequently, in 1976, anthracnose had not been of practical importance in North America for the previous 20 years.

In the summer of 1976 an outbreak of anthracnose in southern Ontario was confirmed to be caused by the delta race, and to a lesser extent by the lambda race, both new to Canada. Most commercial cultivars are still susceptible to these races, but the *Are* gene provides resistance to delta and lambda. The fungus can also infect many other types of beans, such as lima beans and mung beans.

Symptoms

Although infection may occur on both sides of the leaf and on the petiole, early signs of infection usually appear on the lower leaf surface along the veins, which show brick red to purplish red discoloration. Later, such discoloration also appears on the upper leaf surface. At the same time, brown lesions of various sizes, with either black, brown, or purplish red margins, develop around small veins (Plate 1).

Dark brown eyespots that develop longitudinally along the stems are an early sign of stem infection. In the young seedling, the eyespots enlarge and the stem may break off. On older stems, the eye-shaped lesion is limited to an approximate length of 5–7 mm, and the lesion often has a sunken cankerous center.

The most striking disease symptoms are small brown specks on rusty brown spots, which appear on the pods. As the spots enlarge, their centers turn brown and many tiny black specks appear randomly on the brown area, replacing the brown specks. Each of the tiny black specks contains a mass of pinkish spores, often visible as a viscous droplet in humid conditions. The lesions on the pod usually reach a diameter of 5–8 mm. They are slightly sunken at the center and have a dark brown or purplish brown margin (Fig. 1).

The seeds obtained from heavily infected pods may show brown to light chocolate-colored spots on the seed coats (Fig. 2). In badly infected seeds, the lesions may extend into the cotyledon.

Mode of infection

The initial infection comes from fungus propagules that are carried in the seed or, to a lesser extent, in bean straw. The fungus remains alive in the seeds as long as

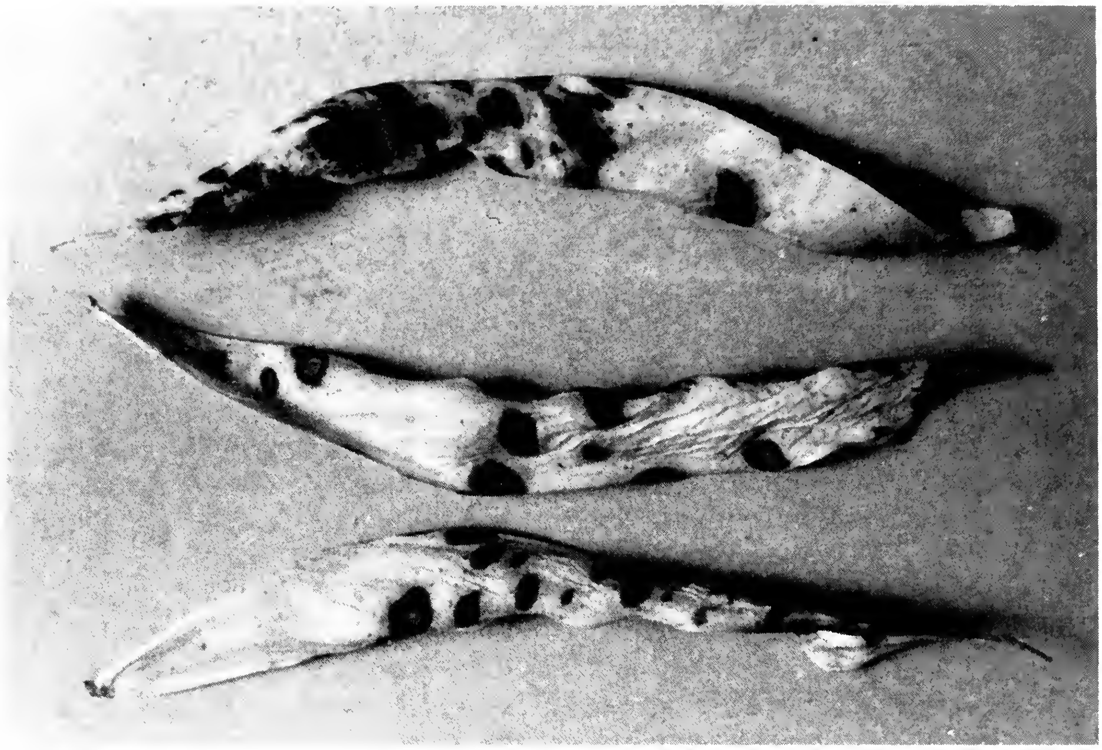

Fig. 1 Pods of anthracnose-diseased white beans showing rusty spots.

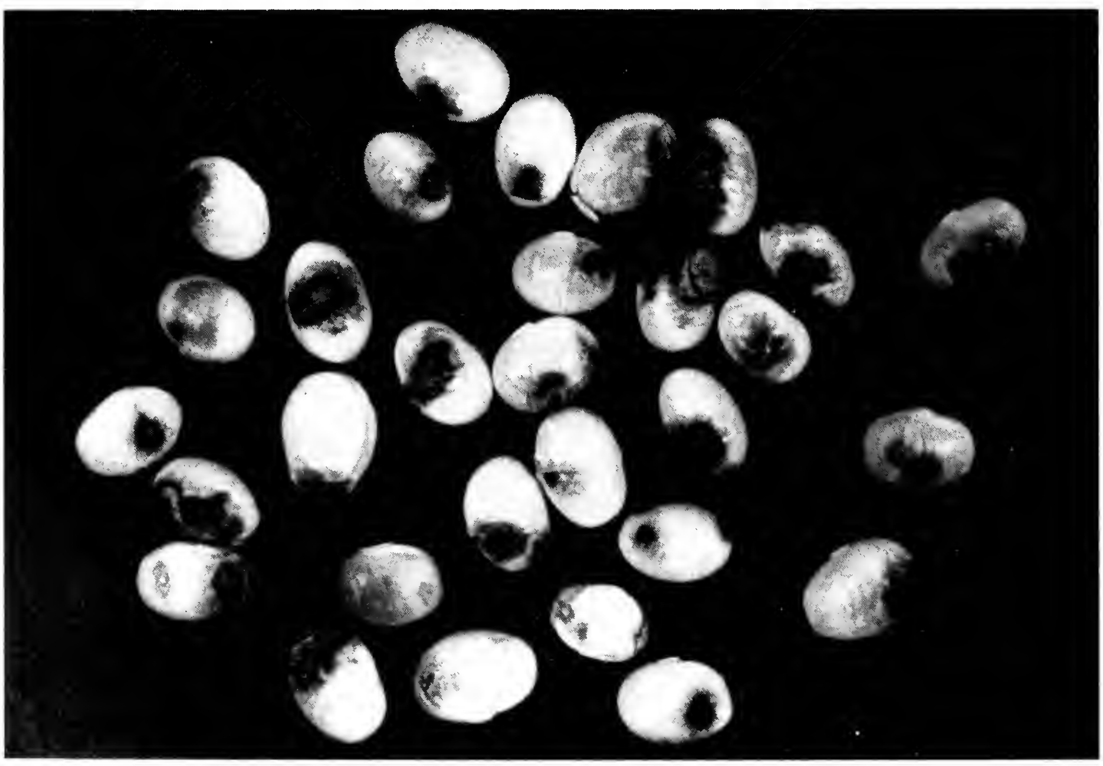

Fig. 2 Anthracnose on pea bean seeds.

the seeds are viable. In the field, recent research shows that the fungus can survive over the winter only in dry straw, not in wet or buried straw.

After the initial infection, the disease is spread by spores carried in splashing raindrops, by machines, or by people. Splashing raindrops blown by gusting winds cause a spread of 3–5 m.

Control

The most desirable method of controlling this disease is by planting resistant cultivars. If they are not available, certified disease-free seed, treated with an effective fungicide, should be used.

Because the fungus cannot overwinter in debris buried in the soil, plowing down diseased bean refuse in the fall is advisable. Crop rotation is also helpful.

White mold

White mold, also known as sclerotinia rot or sclerotinia wilt, is caused by *Sclerotinia sclerotiorum*. The causal fungus attacks a wide range of hosts and has worldwide distribution on numerous field crops and vegetables. White mold frequently causes serious losses in dry beans and green beans across Canada. The occurrence and severity of this disease are difficult to predict. However, the disease appears more frequently and is more severe in fields with a previous history of white mold. This is understandable, because the fungus can survive in the soil for many years by means of sclerotia, which are hard, weather-resistant survival structures. Fields with a previous history of white mold tend to have a high density of sclerotia.

In Canada, the organism thrives from mid July to late August, when weather conditions are warm and humid, and especially when the petals fall. Fallen petals provide an excellent site for this fungus to establish its infection in bean plants. If favorable weather conditions prevail, secondary spread is very rapid. Dry weather tends to check its spread.

In southern Ontario, the degree of white mold infection varies from field to field, from a trace to 100%. Such differences in disease severity are probably attributable to variation in precipitation, soil drainage, cultural practices, and sclerotial density in various localities.

Fields planted densely with vine-type bean cultivars tend to develop heavier infection than those planted thinly with upright cultivars.

Symptoms

Infection usually takes place at the junction of leaf petiole and stem, approximately 10–15 cm above the soil level, where fallen flower petals or leaves have adhered. The infected petioles at first show water-soaked lesions, which spread rapidly to the stems and branches. Later, the superficial cottony growth of white mold occurs on the infected petioles, stems, and pods. As the disease advances, the infected parts display a brownish to chocolate brown discoloration, and a soft rot results in dieback to the branches (Plate 2). At this stage, the fungus forms many hard, black overwintering bodies (sclerotia), about the size of a wheat grain, on or inside the infected plants (Plate 3).

Mode of infection

Primary infection results from the spores discharged by tiny (2–5 mm) funnel-shaped fruiting bodies (apothecia), resembling tiny toadstools, which are produced from the overwintered sclerotia lodged near the soil surface. A long period of cool, wet weather promotes the production of the apothecia. Each apothecium discharges millions of airborne spores, which germinate and infect plants. It has been reported that about three sclerotia per square metre cause 60–95% of a field of kidney beans to become infected. Fallen flower petals or leaves that become lodged in the junction of petiole and stem are usually the site from which initial infection is established.

Secondary spread occurs along plant parts in natural contact. The fungus produces sclerotia on the infected pods and stems of the plant and they become dislodged, falling into the soil, often during harvesting. They are then plowed into the soil at various depths, where they remain viable for several years, up to 20 years at least. Only sclerotia within 3 cm of the soil surface are capable of producing fruiting bodies in the following season; the others become dormant but germinate if they are raised to the soil surface by subsequent cultivations.

Control

Fungicides can be effective if they are applied properly; the timing of spray and method of application have a great impact on results.

Some cultivars are more tolerant than the others; for example, Ex Rico 23 is highly tolerant, and some green beans such as Bountiful, Stringless Green Pod, and Golden Wax are reportedly tolerant. These tolerant cultivars may provide some control in fields with a history of heavy infection and can be further supplemented with a chemical spray.

Generally speaking, cultivars that have upright characteristics, with less viny, smaller canopies, tend to develop less white mold. A heavy canopy of crops reduces air circulation, so that fallen petals remain stuck on leaves and stems and provide infection courts for the fungus. Air circulation between rows of beans can be improved by planting the rows parallel to the prevailing winds, by reducing the seeding rate, and by practicing stringent weed control. However, reducing the seeding rate often reduces bean yield as well.

Crop rotation is not fully effective because the fungus can survive in the soil for many years in the absence of bean crops. Besides, the fungus has a very wide host range; nearly 150 crops in North America are susceptible to the disease. Cereals and corn are not hosts and can be used in rotation.

Rust

Bean rust (*Uromyces phaseoli*) is present in every bean-growing area in the world. In North America, the problem is more serious in the United States than in Canada. In the United States, bean rust prevails in regions of high altitude such as Colorado, Wyoming, and Montana, where summer is typified by warm days and cool nights. Such climate is conducive to dew formation and perpetuates infection and spread of rust. In Canada, although rust is frequently found, it occurs sporadically and usually affects only a few plants in a field. Only on rare occasions do a few fields develop heavy infection.

Symptoms

Although infection occurs mostly on leaves, it can also occur on petioles and pods. In severe cases the stem may also be affected. The first sign of rust infection is the occurrence of many minute white spots that are slightly raised and are often surrounded by a yellow halo. The spots later break open, and a pustule of pale brown spores appears (Plate 4). These are summer spores, which can be spread by wind, tools, insects, and animals, thus infecting other plants. This process can be repeated several times in a summer. Under favorable conditions, a cycle takes 7–10 days. On pods, the tissue surrounding the pustules often remains green when the pods mature and turn yellow. These characteristic green spots are referred to as green islands (Plate 5). Severely infected leaves shrivel, and heavily infected plants result in early defoliation. In northern countries like Canada and the United States the spore masses turn dark brown or black in the fall because thick-walled winter spores are produced. However, in southern countries like Mexico and Puerto Rico, where the climate is warm and beans are grown year-round, summer spores are produced repeatedly throughout the year.

Mode of infection

In northern countries, the primary infections are caused by winter spores, which overwinter and germinate in the spring, and by summer spores, which are brought in by wind dispersion from southern locations. The infected plants produce their first crop of summer spores in 5–7 days. The process can be repeated indefinitely, as long as the temperature is moderate (15–25°C) and free moisture is available (at least 4–6 hours). Thus, secondary spread is achieved by summer spores.

Control

The disease causes minimal damage in Canada. Should it become a problem, use a resistant cultivar if it is available or spray with fungicides following provincial recommendations.

Powdery mildew

Powdery mildew of beans is caused by *Erysiphe polygoni*. The fungus can also attack many genera of perennial hosts, including alfalfa, clover, and vetch. In North America, this disease occurs frequently on snap beans in the fall in the southern United States and the Pacific Coast. Yield loss of up to 50% has been reported. In Canada, although the disease usually occurs in the fall, it is not severe and has little effect on yield because the beans are generally harvested in the early fall. Also, because the fall season advances rapidly in northern countries, the period for the spread of disease is curtailed.

Symptoms

Although the fungus can attack all plant parts above ground, the disease occurs first on the leaves. The early signs of infection are rather inconspicuous; the infected areas appear slightly dull and dark green. Later, superficial white powdery spots (Plate 6) develop in these areas. The white spots enlarge and coalesce to eventually cover the whole leaf. The spots consist of the mycelia and conidia of the

mildew fungus. Severely affected leaves and pods may be malformed or distorted. Later in the fall, the white spots turn gray to dark gray and minute black dots (cleistothecia), which are the overwintering structures, may be found.

Mode of infection

There are two sources of primary inoculum; one is conidia produced from the overwintering mycelium in perennial hosts and the other is ascospores released from cleistothecia overwintered on the infected plant debris. It is believed that ascospores play a minor role as primary inoculum. Unlike most fungus spores, which require high humidity or free water to establish infection, the conidia of powdery mildew can germinate and infect the host in a wide range of humidity. Some races are adapted to very dry atmospheric conditions. Secondary spread is achieved by wind-borne conidia, which appear as a white powder on infected leaves.

Control

It is known that bean cultivars vary in their resistance. Some are highly resistant and should therefore be used in areas with a high incidence of disease. Several fungicides are highly effective in controlling the disease.

Seed rot and damping-off

Beans sown in cool, poorly drained soil often have severe seed rot and damping-off. Severely affected fields may have to be reseeded.

Many factors contribute to seed rot; poor quality of seeds and adverse soil and weather conditions are important contributing factors. Seeds with poor germinability and high fungal infestations are likely to have high percentages of seed rot. Cold, wet weather, which delays seed germination, favors the disease. Seed rot is caused by many soil organisms, including species of the fungi *Pythium, Rhizoctonia, Fusarium, Phytophthora*, and many soil bacteria.

Damping-off is caused by the same groups of organisms. However, *Pythium* species are usually the major causal organisms. These fungi attack the hypocotyl of the germinated seedlings, which die in a few days.

Symptoms

Seeds affected by seed rot never emerge. If they are removed from soil, they show symptoms of soft rot. Some seeds are slimy and others are covered by fungi of various colors.

Damping-off attacks the hypocotyl of the newly emerged seedlings at the soil line. The freshly invaded hypocotyl develops water-soaked lesions that extend rapidly along the hypocotyl in either direction. Later, the affected hypocotyl shows a typical brown-colored soft rot. Upon the onset of dry weather, the affected plants become dry and shriveled.

Mode of infection

Damping-off fungi are soil inhabitants. They can survive for many years in soil in the form of thick-walled spores (i.e., oospores or chlamydospores) and hard mycelial bodies (sclerotia). These resting structures germinate in the presence of

hosts to achieve primary infection. Secondary spread occurs in surface water, which carries spores and sclerotia from the diseased seedlings to the healthy ones. Such spread is particularly effective in species of *Pythium* and *Phytophthora* in which swimming spores (zoospores) occur. The disease ceases to spread at the onset of dry, warm weather.

Control

Good-quality seeds that are free of discoloration and cracks and that germinate strongly should be used. Seeds should be treated with a chemical protectant and planted in warm, well-drained soil.

Root rot

Some of the damping-off organisms cause root rot later in the season. *Rhizoctonia solani, Fusarium solani*, and *Pythium ultimum* are fungi commonly isolated from the diseased roots. In addition, several other species of *Fusarium* and *Pythium* can also cause root rot of beans. Root rot is present in every soil, and nearly all plants in a field have some degree of root rot. The impact of root rot on yield depends on the growth of replacement roots and on the soil conditions that affect root growth. Weather conditions during the summer and excessive nitrogen also affect this disease. Compact and poorly drained soils tend to have more root rot, but if enough roots remain or if the plant is able to grow new roots and sustain normal plant growth, the yield will not be severely limited. However, under conditions of high soil moisture, yield loss may be substantial.

Symptoms

Root rot fungi can attack both the main taproot and the secondary roots at various stages of growth. The affected secondary roots show dark brown rot and many break away at the areas of root rot. The affected taproot develops cankers and various discolorations—brown, reddish brown, or dark brown—on the root surface. Inside the root, the discoloration advances up the central portion of the stem. Discolorations vary somewhat with the causal fungus and the extent of the disease (Fig. 3). The disease symptoms also vary with the causal fungus. For example, *Phythium* causes wet rots and *Fusarium* and *Rhizoctonia* cause dry rots. The disease disrupts the uptake and transport of water and nutrients. Plants less severely affected may wilt on warm days, remain stunted, and grow poorly. Severely affected plants wilt quickly and die.

Mode of infection

Root rot fungi are common soil inhabitants. Their mobility in the soil is somewhat limited and they attack only the roots that come in contact with them. All root parts are susceptible but become less so when the roots grow older and tissue becomes more woody. The disease can spread from infected taproots to the stem by internal fungal growth. Later, the fungus sporulates inside or on the surface of the infected tissues and the spores can reinfect other roots on contact. Later in the season, various root rot fungi produce overwintering spores (oospores or chlamydospores) and resting bodies (sclerotia).

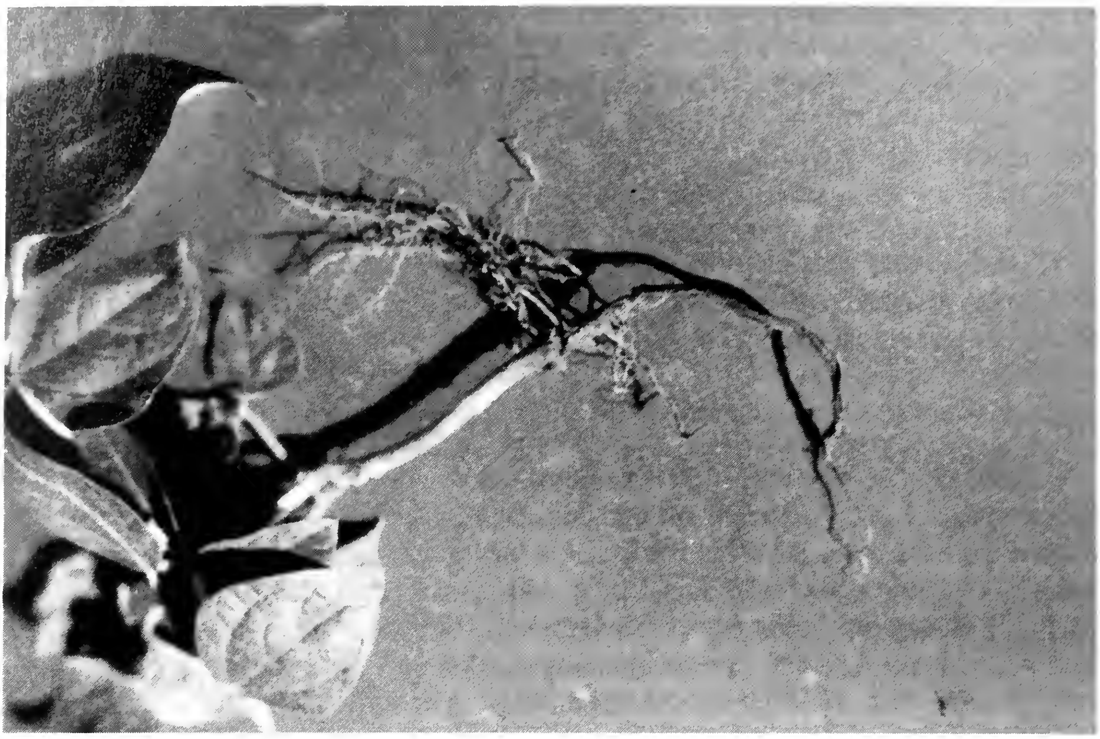

Fig. 3 A portion of basal stem of beans showing discoloration caused by root rot.

Control

The root-rot effect can be decreased by adequate crop and soil management. Proper drainage, aeration, crop rotation, and fertilization reduce damage from root rot. Use tolerant varieties if they are available, as recommended by your provincial agricultural representative.

White-bean discoloration

Dry beans harvested after a wet growing season have a high percentage of discolored beans, resulting in a lower grade and a lower price. The discoloration is caused by *Alternaria alternata*, a black fungus. Early maturing cultivars are more subject to discoloration than late maturing cultivars.

Symptoms

Discolored beans vary from light to dark gray and are occasionally streaked with brown. They are more likely to have wrinkled seed coats (Fig. 4) and have a slightly lower germinability than do normal beans. Seed discoloration is a direct result of pod discoloration, which becomes apparent upon pod maturation (Fig. 5). Pods that show discoloration at maturity usually have some degree of pod flecking when they are still green. Severely discolored pods often contain seeds with varying degrees of seed discoloration.

Mode of infection

The causal agent, *A. alternata*, is a leaf-inhabiting fungus common in bean fields and is a weak parasite that colonizes the cavities of stomata and causes

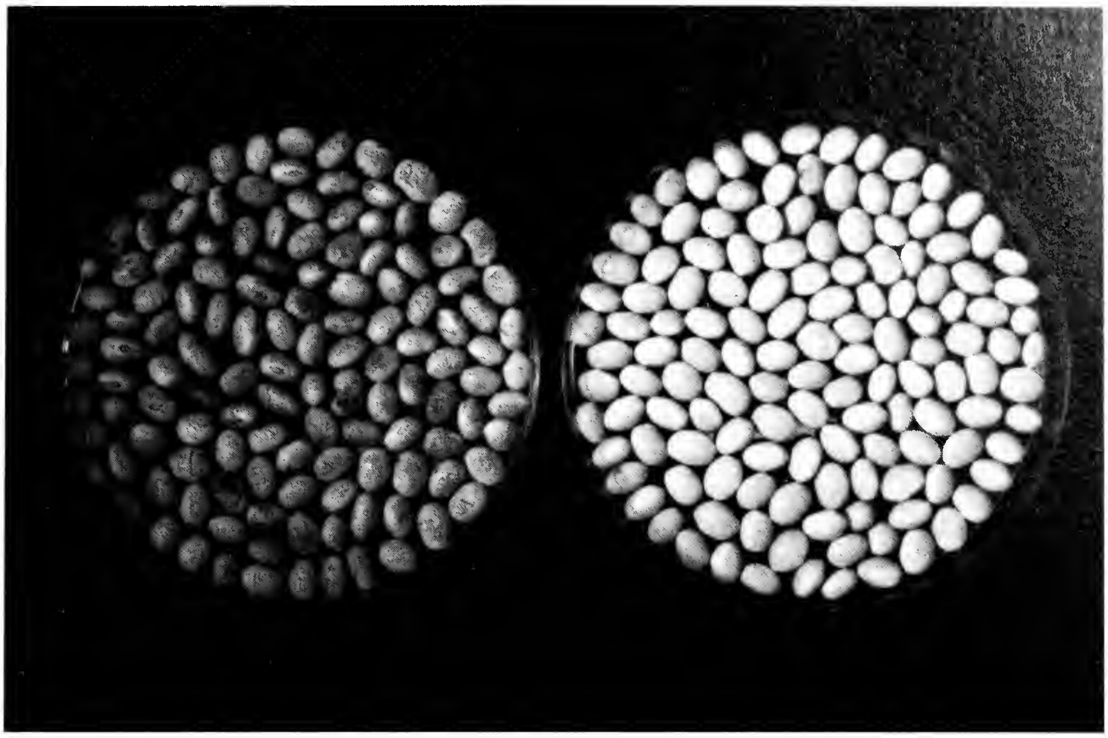

Fig. 4   Dry beans that are discolored (*left*) and normal (*right*).

Fig. 5   Comparison of discolored pods (*left*) and normal pods (*right*) of white beans.

restricted infection. The fungus thrives on senescent tissues and sporulates readily. Benomyl and chlorothalonil, used for controlling white mold, significantly increase the incidence of discoloration. The discolored pods carry numerous spores of *A. alternata* and a water-soluble blackish brown pigment that smudges the dry bean.

Control

To prevent seed discoloration, the following measures are recommended:

- Control white mold with chemicals registered for that purpose.
- Harvest beans as soon as they are dry. Wet weather conditions promote growth and sporulation of the fungus and allow the dark pigment to move from the pod to the seed coat.
- Do not harvest beans if they are not dry enough. High moisture in the seed promotes growth and sporulation of the fungus during handling and storage, particularly in warm and humid weather conditions.
- Dry beans as soon as possible if the moisture content is high.
- Do not mix bean lots of various moisture content. *A. alternata* may grow in pockets of higher moisture during storage.

Gray mold

Gray mold is caused by the fungus *Botrytis cinerea* and occurs more often in transit and storage than in the field. Warm and humid conditions favor the disease. The conditions that promote white mold disease are generally conducive to gray mold. However, gray mold has not caused significant loss in Canada.

Symptoms

Although gray mold can attack all parts of the plant above ground, it is found more often in pods and leaves than on the stem. Affected pods and leaves show soft rot and slightly greenish discoloration. As the soft rot expands, a grayish mold emerges on the old infected areas. The mold later turns to powdery masses of grayish brown spores. A cloud of spores is dispersed when the infected plants are disturbed by wind or machinery. If the environment becomes dry, the infected tissues shrink and dry. The mummified tissues are dark brown (Plate 7).

Mode of infection

The fungus is present on almost all plant debris on and in soil and infects the pods or leaves that come in contact with soil first. Raindrops may splash the spores from the soil to various plant parts. Fallen blossoms or leaves that adhere to plants are an excellent site of infection. Secondary spread is accomplished largely by wind-borne spores and to a lesser extent by contact. Tissue damaged by any agent, such as frost or machinery, is extremely susceptible. Dying and fallen flowers adhering to the pods are usual points of entry.

Control

In general, cultural practices for control of white mold, including wider spacing of rows, thinner planting, and use of upright cultivars, are also effective for controlling gray mold. However, if the disease becomes a problem, effective chemicals are available for spraying.

Plate 1 A bean leaf with anthracnose symptoms.

Plate 2 A close-up view of bean pods infected with white mold.

Plate 3 Hard black structures (sclerotia), which are the overwintering bodies of the fungus, appear on the surface of petioles infected with white mold.

Plate 4 Rust-infected bean leaves showing many pustules of summer spores.

Plate 5 Rust-infected pods with green islands around pustules.

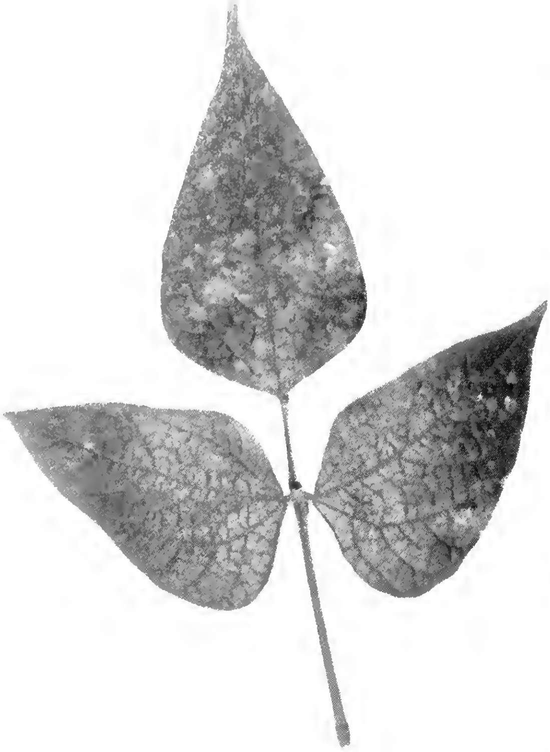

Plate 6 A bean leaf showing disease symptoms of powdery mildew.

Plate 7 Symptoms of gray mold on pods and leaf of bean.

Plate 8 A close-up view of common-blight lesions.

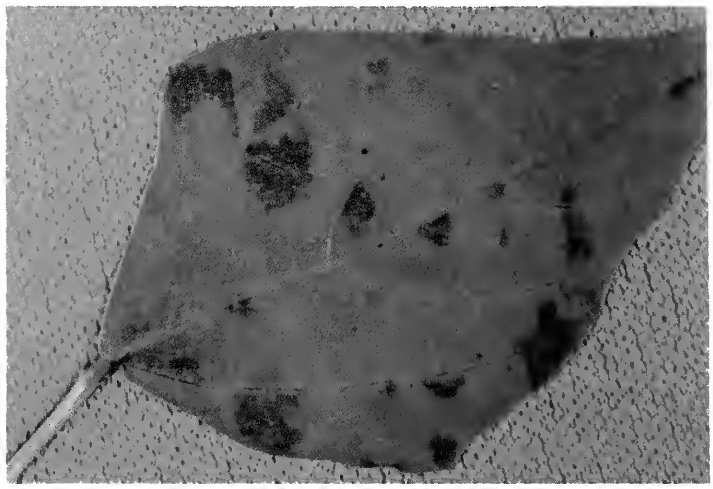

Plate 9 A leaf of Sanilac white bean with typical mosaic symptoms of bean common mosaic virus (race 15).

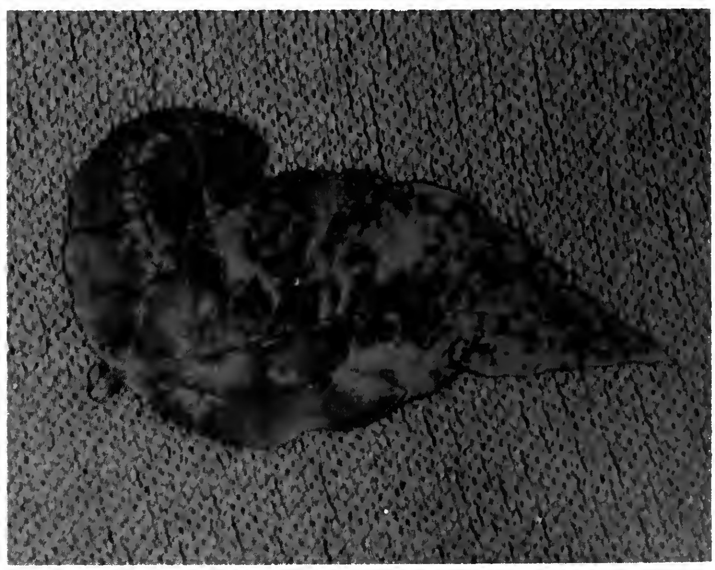

Plate 10 Symptoms of bean common mosaic virus (race 1) infection on a leaf of Refugee.

Plate 11 Leaves with typical symptoms of bean yellow mosaic.

Plate 12 Pods from a plant infected by bean yellow mosaic virus, showing mottling and deformation.

Plate 13 A plant infected by tobacco ringspot virus, showing tip and bud blight and chlorotic spots on the leaves.

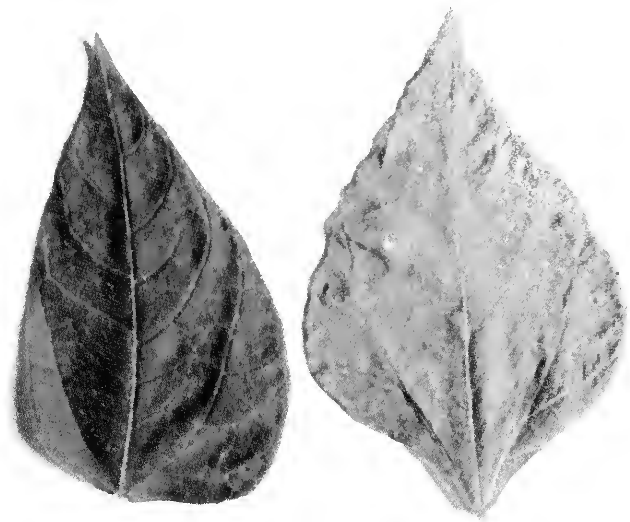

Plate 14 A bean leaf with typical mottling of cucumber mosaic virus infection (*right*) and a healthy leaf (*left*).

Plate 15 A leaf with symptoms of magnesium deficiency.

Plate 16 A leaf with typical symptoms of manganese deficiency.

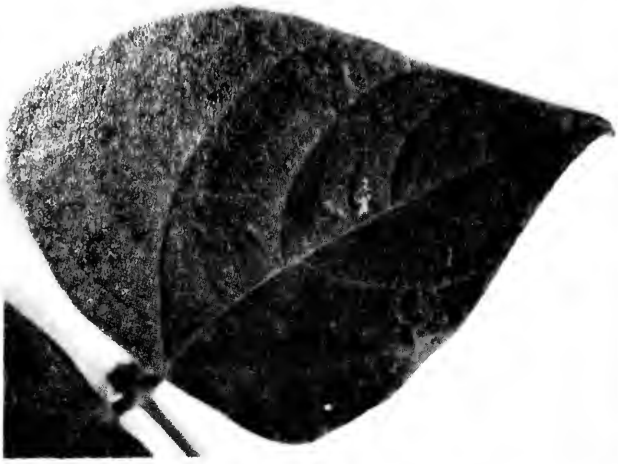

Plate 17 A close-up view showing an ozone-damaged leaf with flecks and stipples on the upper leaf surface.

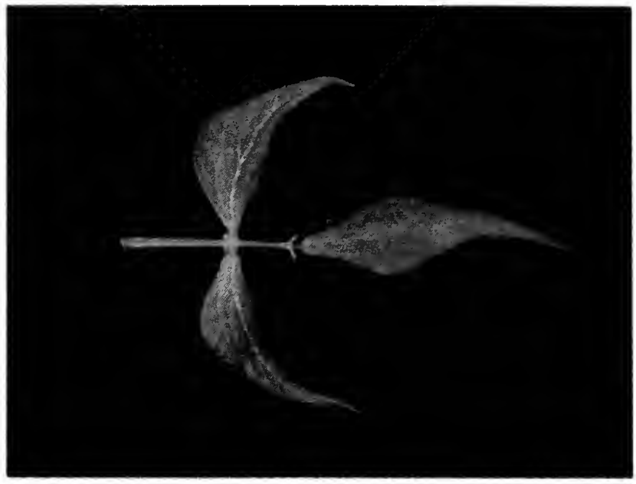

Plate 20 Symptoms of 2,4-D injury on bean leaves.

Plate 18 Leaves with yellow and brown spots caused by leafhopper burn.

Plate 21 Primary leaves of beans severely affected by metobromuron.

Plate 19 Symptoms of the early stage of atrazine injury on primary leaves.

Plate 22 Bean leaves with severe monolinuron injury.

Pod spot

Pod spot caused by the fungus *Cladosporium herbarum* occurs sporadically, affects only a few plants, and has not been a concern in Canada. Weather conditions and culture practices that favor gray mold are conducive to the disease. Pod spot is found more often on pods than on leaves. The infected pods initially show yellowish to grayish discoloration, and later, concentric zonations of rusty or cinnamon brown mold develop at the central area of the lesion. Seeds in the infected pods are usually stained or infected (Fig. 6).

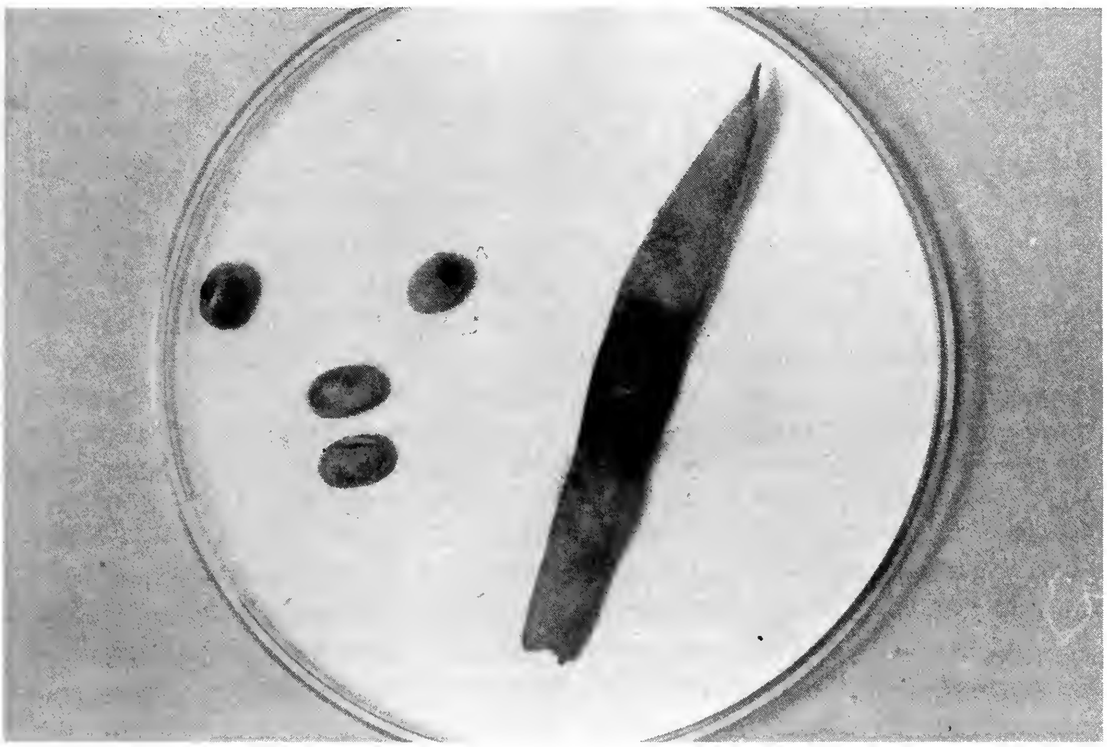

Fig. 6 A pod and seeds showing typical symptoms of pod spot.

Angular leaf spot

Angular leaf spot (*Isariopsis griseola*) has attacked beans grown at high altitudes in Central and South America but has not been a problem in Canada. The infected leaves develop small, angular, dark brown spots. The angular-shaped spots are formed because the infection that occurs in the interveinal tissues is limited by the network of veins. Severely diseased plants may suffer complete defoliation. The fungus can be carried in the infected seeds as dormant mycelium or over the season in infected debris.

Bacterial diseases

There are over 10 bacterial diseases known to affect beans, of which four are of importance in Canada. They are common blight, fuscous blight, halo blight, and

bacterial wilt. The life histories of these causal bacteria are almost identical. Also, their mode of infection is similar and they are controlled in similar ways.

Common blight and fuscous blight

Common blight and fuscous blight are caused by *Xanthomonas phaseoli* and *X. phaseoli* var. *fuscans*, respectively. The symptoms of these two diseases are almost identical. The two organisms can be distinguished only in the laboratory, but *X. phaseoli* var. *fuscans* in culture media can infect cultivars not ordinarily attacked by *X. phaseoli*. Thus, the proportion of common and fuscous blight in a given area may depend on the cultivars used. These diseases usually occur in late July and August and become progressively more severe as beans approach maturity.

X. phaseoli and *X. phaseoli* var. *fuscans* are the most important bacterial diseases in Canada. Several years ago, more than half the bean crop in Ontario was affected by them. However, they have been brought under control by imposing a strict seed certification program that ensures a supply of disease-free seeds. The program includes production of Breeder seeds in Idaho, where bacterial blights are minimal, and of Select and Foundation seeds in Ontario, where strict field inspections are conducted yearly.

Symptoms

The initial symptoms usually occur on the leaves. Infected leaves develop water-soaked or pale green spots that later turn brown and dry. These spots may coalesce to form irregular blotches of varying size. However, each spot or blotch invariably has a narrow chlorotic margin around it (Plate 8). Severely affected leaves may shrivel and die. Similar spots may occur on the pods; however, they appear somewhat cankerous and greasy. The pod spots may combine to form blotches that frequently have a reddish brown discoloration.

Mode of infection and control

See bacterial wilt.

Halo blight

Halo blight, caused by *Pseudomonas phaseolicola*, is found in every bean-growing area in North America. However, it is less important than common and fuscous blight. Cool temperatures favor the disease.

Symptoms

At temperatures around 20°C, the infected leaves produce small water-soaked spots with a wide, greenish yellow halo. Later, the center turns brown and becomes necrotic. The spots may also coalesce into irregular blotches. At high temperatures, the infected leaves may develop many small reddish brown lesions without a distinct halo. On the pods, the lesions give a more distinct water-soaked and greasy appearance than those of common blight. The lesions may coalesce into blotches of various size. The pod lesions often have a slightly depressed and cankerous center, where creamy bacterial ooze may be formed.

Mode of infection and control

See bacterial wilt.

Bacterial wilt

Bacterial wilt, caused by *Corynebacterium flaccumfaciens*, is not an important disease in Canada. The disease affects the vascular bundles and prevents the normal flow of water and nutrients.

Symptoms

At the early stage, leaves of the diseased plants become droopy on warm days and regain their turgidity during the night. As the disease progresses, the vascular bundles are plugged by bacteria, and the plants wilt and die. The vascular bundles in the stem of the diseased plants show brown to dark brown discoloration.

Mode of infection

All four bacterial diseases have a similar mode of infection. The bacteria can overwinter in infected debris and survive many years in the infected seeds, which therefore constitute the source of primary infection. Infection takes place through wounds or natural openings, such as stomata or guttation pores. Secondary infection occurs by splashing raindrops or by people, animals, insects, or machines that come in contact with the diseased plants. Gusting rainstorms can spread the disease for a considerable distance.

Control

Various cultivars appear to have varying degrees of tolerance or resistance to all four bacterial diseases, but none is immune to all strains of a given organism; thus breeding for resistance has not been very successful. The use of disease-free seed and the practice of crop rotation have been the most effective and successful measures for controlling these bacterial diseases. Good sanitation practices, such as disking plant debris, avoiding entering the field when plants are wet, and cleaning machines and tools after they come in contact with diseased plants, should reduce the spread of disease.

Viral diseases

There are many plant viruses that can infect beans (white, colored, snap, and kidney beans). Among them, bean common mosaic virus, bean yellow mosaic virus, and tobacco ringspot virus are found most commonly in beans in Canada, particularly in southwestern Ontario. Severe losses from these viral diseases have been reported, ranging from moderate to severe, and the incidence of bean yellow mosaic and bean common mosaic diseases is increasing.

Alfalfa mosaic virus and cucumber mosaic virus are frequently found in isolated cases but rarely develop to a significant scale or cause serious damage. Other viral diseases, such as bean pod mottle and white clover mosaic, can be found only occasionally in isolated plants and are not discussed.

Bean common mosaic

Among many strains of bean common mosaic virus (BCMV), strain 1 and New York strain 15 are prevalent in southern Ontario, where most of the Canadian bean crop is grown. The disease can cause severe yield losses in susceptible cultivars.

Symptoms

Susceptible infected plants show mottling and mosaic patterns in the leaves. The infected leaves have irregular light green areas intermixed with dark green patches. The darker areas develop faster than the lighter areas, resulting in puckered leaves (Plate 9). In some cultivars, infected leaves are cupped downward (Plate 10). Bean plants infected early in the season are often dwarfed but generally survive, though they produce fewer and smaller pods than do healthy plants.

Cultivars of dry beans, such as Fleetwood and Seafarer, are normally resistant to the two major races (1 and 15) and are free of disease symptoms. However, at temperatures above 30°C, some of the plants may develop black root and numerous other symptoms. Black root is characterized by light brown to dark brown discoloration of petioles, stems, and roots. Leaves of affected plants usually do not show mosaic patterns or mottling. Plants infected before flowering usually die in mid season and produce few pods. If infection occurs at a later stage of growth, pods set normally, but the plants die before the pod can mature.

Mode of infection

BCMV is seed borne in beans and can be transmitted by aphids from BCMV-infected perennial legumes, such as alfalfa, clover, and vetch. Primary spread of the disease is usually by seeds, but the virus might be carried by aphids after feeding on overwintering perennial legumes. Secondary spread is achieved by aphids and perhaps by machines or tools that are contaminated by the virus.

Control

A satisfactory method of controlling the disease is to grow resistant cultivars. If a nonresistant cultivar is used, the following precautions should be taken to prevent BCMV infection:

- Use certified virus-free seed, because the virus remains active as long as the seed is viable.
- Do not plant beans adjacent to vegetable or other crops that are breeding grounds for the aphid vectors.
- Eliminate perennial legume crops and weeds in the vicinity of the bean field because they might harbor the virus.

Bean yellow mosaic

There are many strains of bean yellow mosaic virus (BYMV). The symptoms caused by the various strains range from mild to severe. A severe strain of this virus occurs in southern Ontario, and some seed growers' plots are severely affected.

Symptoms

BYMV-infected plants show rapid wilt and dieback of tips or branches. Later, a light brown to dark brown vein discoloration spreads to petioles and stems. Infected plants usually develop numerous lateral shoots with small leaves. The newly formed leaves show severe mosaic symptoms, with yellowing and curling but not much puckering (Plate 11). The older leaves are somewhat tough and leathery and drop from the stem easily. Mottling and deformation of pods are common (Plate 12). In many bean cultivars, inoculated primary leaves develop chlorotic local lesions that later turn brown and become necrotic.

Mode of infection

BYMV is not seed-borne in beans. The primary source of inoculum is infected perennial legumes; approximately 20% of alfalfa, clover, and vetch with mosaic symptoms carry BYMV. Secondary spread is by aphids and perhaps by machines or tools contaminated by the virus.

Control

In areas with a high incidence of BYMV, resistant cultivars should be used. To avoid the disease, beans should not be grown near vegetables or other crops and weeds, which might be sources of aphids, or near perennial legumes, especially yellow sweetclover and certain flowers, such as gladiolus.

Tobacco ringspot

Tobacco ringspot virus (TRSV) can infect a wide variety of crops, including beans, and can cause severe losses, depending on the cultivar and the virus strains.

Symptoms

Symptoms of TRSV infection vary greatly in various cultivars of beans. For some, infection results only in systemic chlorotic spots, mottling, mosaic patterns, or rugosity; for others, however, it can result in severe necrosis and bud blight (Plate 13). If infection takes place in an older plant, leaves become somewhat leathery, and brown streaking develops in petioles of leaf veins. In general, infected plants are dwarfed, pod set is reduced, and the pods are underdeveloped or aborted. Mottling or yellowing blotches later turn brown.

Mode of infection

Although seed transmission of TRSV is common in soybeans, it is rarely transmitted through seeds in other beans. No insects have been positively identified as vectors. The virus can be transmitted by abrasion and by the soil-borne nematode *Xiphinema americana*, and may overwinter in the nematode vector or in perennial hosts such as white clover and gladiolus. It is possible that the virus is transmitted from one field to another through infected soybean seeds and then is picked up by its nematode vector. Later, when beans are introduced into that field, the nematodes feed on the bean roots and transmit the virus to bean plants. Since

this virus can also be transmitted by contact, machines or tools that cause injuries to plants may also spread it.

Control

To prevent infection with TRSV, avoid planting beans (especially soybeans) in fields with a history of TRSV disease, because virus-carrying nematodes can persist in the soil for many years. Avoid spreading the virus by machines or tools.

Cucumber mosaic

Cucumber mosaic virus (CMV) is a very destructive and widespread virus that affects more than 30 plant families, including vegetables, field crops, ornamentals, and weeds. Although CMV does infect beans, it is rarely found in commercial dry-bean fields; however, it is seen frequently in snap or garden beans in areas where many different vegetable crops are grown. In the bean field, the disease usually starts near the edge of the field and progresses toward the center.

Symptoms

Depending on bean cultivars, symptoms on leaves range from mild to severe mottling. The mottled areas are a slightly translucent greenish yellow. Slight puckering and epinasty (Plate 14) are also common. The diseased plants are somewhat dwarfed, the internode is shortened, and the pod set is reduced. Mottling is also visible in green pods. Although the disease can cause yield reduction in snap beans, it rarely kills the plant.

Mode of infection

There is little evidence that CMV is seed borne. CMV overwinters in a variety of perennial weeds and ornamentals, and the primary inoculum can be transmitted from them to annual crops by more than 60 species of aphids. In the bean field, it is spread by aphids and by contact with contaminated tools, machines, and people.

Control

Beans should be planted away from vegetables. Aphid control should reduce the incidence of this disease. Control of perennial weeds is also essential.

Alfalfa mosaic

Alfalfa mosaic virus (AMV) is reported to infect more than 70 genera and 200 species of plants, but alfalfa and clover are mostly responsible for the perpetual problem of this disease, which occurs in many pulse and oilseed crops. Volunteer alfalfa and clover plants are widespread, and it is safe to say that no field is free of these volunteers. The virus is present in 5–25% of alfalfa and clover stands, especially in those that are older. Thus, AMV is almost certainly present in most fields.

Symptoms

The leaves of infected plants show mottling, and in young leaves the mottling is also accompanied by many small bright yellow spots. In addition, dwarfing and vein browning may be developed in the more susceptible cultivars. On the more

resistant cultivars, only minute necrotic spots may be developed in the leaves. Pods are free of symptoms.

Mode of infection

Although AMV is seed borne in alfalfa, it is not carried in bean seeds. However, AMV is everywhere in alfalfa, clover, and perennial weeds and it is easily transmitted to beans by aphids from nearby infected plants. In the bean field, AMV is spread by aphids and mechanical contagion.

Control

The percentage of volunteer alfalfa and clover that carry AMV is very high, and therefore these plants, along with other weeds near the field, should be destroyed. Insect control, particularly of aphids, in bean fields and in nearby forage fields may reduce the incidence of disease. If possible, a bean field should not be located adjacent to a forage field.

Other diseases

Witches'-broom

Witches'-broom is caused by a species of mycoplasma but is of little economic importance in beans. However, it is worth mentioning because it represents a totally different category of disease. Diseases caused by mycoplasma-like organisms are many and are usually referred to as aster yellows, phyllody, witches'-broom, dwarf, stunt, or bushy stand. They were thought to be caused by viruses until late 1960, when the causal organisms were revealed to be mycoplasmas. These organisms cause disease in a wide range of hosts, such as florist crops, legumes, vegetables, cereal crops, fruit trees, and weeds.

Symptoms

On beans, the infected plant is dwarfed and the internode shortened. The infected plants produce extra shoots, and thus the plants are shooty and leafy. Petioles are borne at wide angles, and flower peduncles are often elongated and wavy. The leaves may curl slightly and later become somewhat yellow. Pod sets are largely reduced. However, death seldom occurs in the beans.

Mode of infection

Mycoplasmas are harbored in perennial and biennial weeds and in eggs of infected leafhoppers in which they can propagate, passing through the eggs. Leafhoppers are the most important vectors that transmit the disease, but there are other means of disease transmission, namely by grafting scions and by parasitic dodder plants.

Control

Control of leafhoppers by insecticides and removal of perennial and biennial weeds are the key to avoiding this disease.

Root knot

Root knot of bean is caused by nematodes, *Meloidogyne* spp., which also attack a large number of cultivated and wild plants. The nematodes are distributed throughout the United States and many agricultural areas in Canada. *M. hapla* can overwinter in the northern United States and in Canada and is generally referred to as the northern nematode. The southern nematode, *M. incognita*, does not overwinter in Canada and can be found only in greenhouse soil. In general, nematode problems are more severe in the southern United States, particularly in sandy soil.

Symptoms

Above the ground, the symptoms are usually identical to those of the early stage of root rot. The affected plants appear weak, slightly yellowish, and stunted. The leaves are somewhat droopy on warm days. However, the symptoms on the roots are distinctive. There are many galls and enlargements of various sizes on the roots. Unlike root nodules, they are enlargements of root tissue and cannot be easily dislodged without breaking the root. The roots of the diseased plants are shortened and their efficiency reduced.

Mode of infection

The northern nematode overwinters in fields in the form of larvae and eggs, and the southern nematode survives in greenhouse soil. In response to cold conditions, the former usually moves deeper into the soil in the fall and then moves back to the surface in the spring. The larvae feed on plant roots and cause injuries and galls.

Control

In fields where the nematodes are known to be present, soil fumigation can be undertaken but is too expensive, so that crop rotation is the most practical control. Unfortunately, neither method is totally effective.

Nutrient deficiencies

Bean plants suffer from a number of physiological disorders, many of which are caused by nutrient deficiency. However, with modern fertilizers, deficiencies of major elements such as calcium, potassium, and phosphorous are rare. Plants tend to be deficient in the minor elements, such as magnesium, manganese, molybdenum, zinc, and copper. Magnesium and manganese deficiencies occur most frequently.

Magnesium deficiency

Magnesium deficiency occurs most commonly in sandy soils and can be aggravated by indiscriminate liming with calcitic limestone or heavy application of potassium fertilizers.

Symptoms

Magnesium deficiency causes chlorosis of the leaves, particularly in the interveinal areas (Plate 15). The chlorosis occurs first on the older leaves, as the magnesium is withdrawn from older leaves to younger ones, and progresses upward. Severely affected plants become stunted, and chlorotic leaves roll upward.

Control

Foliar sprays of a water-soluble magnesium salt, such as magnesium sulfate (Epsom salts), provide a quick remedy to the problem. However, if the soil is known to be deficient, adding magnesium sulfate to the soil before seeding may be more economical. Dolomitic limestone should be used whenever lime is required.

Manganese deficiency

The availability of manganese in the soil is frequently determined by the soil pH; a pH value of 6.8 or higher renders the manganese unavailable to beans.

Symptoms

The initial symptoms on the leaves are chlorosis between the small veins. Later, the chlorotic areas may turn yellow and the tissue dies. The affected plants are dwarfed (Plate 16).

Control

When plants develop deficiency symptoms the quickest remedy is to spray the bean foliage with a solution of manganese sulfate. For a long-term solution, manganese salts should be added to the soil.

Toxicity disorders

Bronzing

Ozone is a common industrial air pollutant that can cause bronzing, found in varying amounts in most bean fields. Sensitivity to ozone depends on cultivar, growth stage, and plant health. Some cultivars are more tolerant than others; early maturing cultivars, such as Seafarer, appear to be more susceptible. Older plants and plants affected by root rot and water stress are more prone to ozone damage. Yield losses are difficult to assess accurately, but in some years, losses of up to 40% have been attributed to ozone damage. In Canada, bronzing is particularly severe in industrialized southern Ontario when summer temperatures are high.

Symptoms

Ozone injury is first noticed as small interveinal purple or reddish brown flecks or stipples on upper leaf surfaces. Later, the affected areas turn brown, purplish brown, or red bronze, giving the upper leaf surface a bronzed appearance (Plate 17). Severely affected leaves become chlorotic and senesce prematurely.

Symptoms that resemble ozone injury can also be a result of damage from other causes, such as root rot, sunscald, sandblasting, wind, or normal senescence. Ozone injury develops rapidly in 24–48 hours and affects the entire field fairly uniformly.

Control

Most beans are susceptible to ozone, but the susceptibility varies somewhat among bean cultivars. Avoid planting in fields with a long history of root rot. To reduce damage, use cultural practices that increase plant growth, such as proper application of fertilizer. For instance, in fields where bean yields have been severely curtailed by bronzing or root rots, a preplant application of an additional 100–120 kg of nitrogen per hectare is advisable. It will not prevent bronzing or root rot but will increase yield.

Leafhopper burn

Leafhopper burn is caused by the potato leafhopper (*Empoasca fabae*), which feeds on the bean leaves. It is believed that the burn results from a physiological disturbance brought about by a toxin injected into the leaf by the insect in the process of feeding. Because the disease is restricted to the insect population, it tends to prevail in cool, dry summers, which favor insect propagation. Bean yield may be reduced if the injuries are severe.

Symptoms

The affected leaves show marginal yellowing, reddening, bronzing, and browning with occasional curled-up edges. The burn spots first appear in the interveinal regions between major veins. However, in severe cases the major veins also turn brown. The symptoms resemble those of bacterial blight, except that each brown area is not surrounded by a bright yellow-colored band of tissue (Plate 18). In addition, leafhoppers are present in large numbers in the field.

Control

To control the leafhopper, apply insecticide following provincial recommendations.

Chlorosis induced by excess water

Symptoms

Bean seedlings grown at low spots of a field may show general yellowing and stunting in cold, damp weather. The problem is particularly noticeable in a poorly drained field. These plants are more susceptible to root rot fungi and may not fully recover even after the onset of dry, warm weather.

Control

Improve the surface drainage, and use furrows and catch basins to alleviate this problem.

Herbicide toxicity

Herbicide damage has become a frequent problem and is often confused with disease symptoms. Most herbicides do not injure or kill plants if they are applied correctly. However, the majority of cases are associated with overdose or residue from the preceding crop. Read the labels and instructions carefully, and double-check all calculations before applying chemicals.

Atrazine injury

Injury may occur in fields that were planted with corn the previous year if atrazine was used for weed control, especially if dry weather prevailed in the fall or if high rates were used. Maximum application of atrazine in a previous corn crop can leave sufficient residue to damage or kill bean seedlings. This is particularly obvious in low areas of the field, because residue moves with surface water to the low areas.

Symptoms. The leaves of the affected seedlings develop pronounced yellowing at the leaf edge and at the interveinal areas of the leaf. Only the major vein remains green. The yellowed areas become dry and turn brown to dark brown, showing symptoms of leaf burn. The burned leaves curl, shrivel, and die (Plate 19). The affected seedlings usually die.

Control. Atrazine spray should be adjusted according to the soil type to avoid harmful residual effects. Use herbicides other than atrazine if corn is to be followed by beans. If in doubt, have the soil checked by your provincial agricultural representative for atrazine residues. This can also be done by growing a few seeds in a tray of field soil taken to the greenhouse before sowing the main crop.

2,4-D and dicamba injury

The herbicides 2,4-dichlorophenoxyacetic acid (2,4-D) and dicamba are often used to control broad-leaved weeds in cereals and grasses. However, they are volatile chemicals and may affect an adjacent field planted with broad-leaved crops, such as beans and tomatoes. Minute amounts, particularly of dicamba, can cause noticeable growth distortion of leaves and stems.

Symptoms. The older leaves of the affected bean plants curve downward, and the leaves at the tip tend to curve upward. The veins appear light green, and the tissue between the veins shows mottling. The leaves become thick, stiff, brittle, and somewhat elongated (Plate 20). The symptoms resemble virus-induced bean mosaic, but unlike the mosaic, the stems and petioles of plants injured by 2,4-D and dicamba are somewhat elongated, curled, or twisted.

Control. There are several 2,4-D formulas, and some are less volatile than others. Your choice depends on conditions of application and climatic factors. If you are using 2,4-D or dicamba, avoid wind drift to sensitive crops. Reduce spray pressure to minimize the drift.

Metobromuron injury

Metobromuron is a preemergence weed spray for beans. It often causes injury to beans planted in sandy soil with low organic matter. Under heavy rainfall, some

injury can be caused by treated soil splashing up on the plants. Injury from metobromuron may be increased by atrazine residues in the soil.

Symptoms. The leaves of the affected seedlings develop vein chlorosis. In more severely affected plants, the tissue along the veins also becomes yellow and the tissue between the veins may become somewhat water soaked (Plate 21). The plants usually recover slowly.

Control. Reduce the rate of application on light, coarse soils. Do not use on sandy soil of less than 3% organic matter.

Monolinuron injury

Monolinuron is a preemergence herbicide that also often causes injury to bean seedlings. The injury occurs in heavy rains following application and is more severe in sandy soil. There is also a possibility of injury to the bean leaves from splashing raindrops. Residues of atrazine in the soil may increase monolinuron injury.

Symptoms. The primary leaves of affected plants develop a rapid yellowing that is often accompanied by some degree of water soaking on all parts of the leaf except major veins. The yellowed tissue quickly turns brown and dry. The leaves shrivel and die. Severely affected plants fail to recover from the injury (Plate 22). The symptoms are similar to those caused by metobromuron.

Control. Do not use on light sandy soil of less than 3% organic matter.

Injuries

Sunscald

Sunscald frequently occurs on leaves or bean pods that are directly exposed to sunlight, especially if exposed when wet. Intense sunlight following high humidity and cloudy weather aggravates the problem. Bean plants close to maturity are more likely to be affected than younger plants. Snap beans with sunscald symptoms are reduced in quality.

Symptoms

Sunscald appears first as spots or patches of interveinal browning or bronzing of the epidermis. Later, the brown or bronze patches turn into dead tissue, which is brittle and crumbles easily when dry. On green pods, small brown or reddish spots develop on the part exposed to sunlight. The spots enlarge, coalesce, and become water soaked. They finally become slightly sunken with a tinge of red.

Control

There is no control for sunscald.

Sandblasting

Sandblasting occurs only in beans planted in sandy soil. The damage is particularly noticeable in late spring, when the newly germinated bean plants

encounter violent windstorms in which flying sand dislodges the primary leaves and terminal buds.

Symptoms

Young seedlings lose their primary leaves or buds, or both; sometimes cotyledons are also dislodged, leaving only the hypocotyl. Primary leaves are usually cut at the midpoint of a petiole, resulting in a Y-shaped leafless seedling. The cuts are normally clean and sharp, and the symptoms resemble baldhead that is caused by mechanical injury to the seeds. However, baldhead occurs on scattered plants rather than in large patches.

On the older plants, sandblasting is associated with wind damage of petioles and stems. The affected leaves show brown flecks or bronzing.

Control

If severe damage is done at the seedling stage, replant the affected areas.

Index of pathogens and vectors

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2.5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre